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Notes on elements of the Oligocene flora from the Makum Coalfield, Assam, India

R.C. MEHROTRA[1], DAVID L. DILCHER[2] AND TERRY A. LOTT[2]

[1]*Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.*
Email: rcmehrotra@yahoo.com
[2]*Paleobotany and Palynology Laboratory, Florida Museum of Natural History, University of Florida, Gainesville, Fl. 32611-7800, U.S.A.*
Email: dilcher@flmnh.ufl.edu, lott@flmnh.ufl.edu

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ABSTRACT

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A new species *Daphnogene makumensis* sp. nov. (Lauraceae), plus *Equisetum* sp. both new to the flora, and *Mesua antiqua* Awasthi *et al*. are described from the Tikak Parbat Formation of the Makum Coalfield, Assam, India. The formation is considered Late Oligocene in age. The fossil assemblage indicates the existence of tropical evergreen to moist deciduous forest in the region during the Late Oligocene.

Key-words—Equisetaceae, Clusiaceae, India, Lauraceae, Oligocene, Tikak Parbat Formation.

भारत में असम के माकुम कोयला क्षेत्र से प्राप्त अल्पनूतन वनस्पति तत्वों पर टिप्पणियाँ

आर.सी. मेहरोत्रा, डेविड एल. डिलचर एवं टेरी ए लोट

सारांश

भारत में असम के माकुम कोयला क्षेत्र के टीकाक पर्वत शैलसमूह से *डेफनोजीन माकुमेन्सिस* नवजाति (लॉरेसी) एवं *इक्वीसेटम* जाति दोनों वनस्पति के लिए नई हैं तथा *मेसुआ एंटिक्वा* अवस्थी एवं अन्य को वर्णित किया गया है। इस शैलसमूह की आयु अंतिम अल्पनूतन मानी गई है। ये जीवाश्म समुच्चय अंतिम अल्पनूतन के दौरान क्षेत्र में उष्णकटिबंधीय सदाहरित से आर्द्र पतझड़ी वनों का होना इंगित करते हैं।

संकेत-शब्द—इक्वीसीटेसी, क्लुसिएसी, भारत, लॉरेसी, अल्पनूतन, टीकाक पर्वत शैलसमूह।

INTRODUCTION

The Oligocene sediments exposed in the Makum Coalfield of northeastern India contain a rich assemblage of fossil plants. These plants were first described by Seward in 1912 and subsequent collections provided further information about the flora, composition and its palaeoenvironment (Awasthi *et al*., 1992; Awasthi & Mehrotra, 1995; Mehrotra, 2000; Mehrotra *et al*., 2003). The present paper describes an *Equisetum* stem, one species of a *Daphnogene* leaf, and an update on a previously described *Mesua* fruit.

This study is based on plant impressions collected from the Late Oligocene Tikak Parbat Formation of the Makum Coalfield (27°15'-27°25’N; 95°40'-95°55’E), Tinsukia District, Assam (Raja Rao, 1981; Awasthi & Mehrotra, 1995; Ahmed, 1996). It is the largest coalfield of Northeast India and includes four collieries, namely Baragolai, Tikak, Tirap and Tipong. The open cast mining are in Tikak and Tirap while the other two are underground mines. The generalized lithostratigraphic sequence of the coalfield comprises of Disang, Barail, Tipam and Dihing groups (Raja Rao, 1981; Awasthi & Mehrotra, 1995). The Barail is further divided into three formations, namely Naogaon Sandstone, Baragolai and Tikak Parbat of which the last one is the main coal bearing horizon and comprises medium to fine grained, tough quartzose sandstones, well bedded sandy shales, clays, mudstone and carbonaceous shales.

The coalfield is very rich in plant fossils that generally occur in grey carbonaceous and sandy shales. The taxa already described from this coalfield are *Lannea* A. Rich, *Mangifera* L. and *Parishia* Hook.f. (Anacardiaceae), *Saccopetalum* Benn. (Annonaceae), *Alstonia* R.Br. (Apocynaceae), *Nypa* Steck (Arecaceae), *Avicennia* L. (Acanthaceae), *Santiria* Blume (Burseraceae), *Calophyllum* L., *Garcinia* L., *Kayea* Wall. and *Mesua* L. (Clusiaceae), *Terminalia* L. (Combretaceae), *Bridelia* Willd. corr. Spreng. (Phyllanthaceae), *Dalbergia* L.f. and *Entada* Adans. (Fabaceae), *Apollonias* Nees (Lauraceae), *Barringtonia* J.R. Forst & G. Forst (Lecythidaceae), *Heynea* Roxb. ex Sims (Meliaceae), *Memecylon* L. (Melastomataceae), *Myristica* L. (Myristicaceae), *Podocarpus* L’ Hérit ex Pers. (Podocarpaceae), *Rhizophora* L. (Rhizophoraceae), *Nephelium* L. (Sapindaceae), *Pterygota* Schott & Endl (Malvaceae) and *Sterculia* L. (Sterculiaceae) (Awasthi *et al*., 1992; Awasthi & Mehrotra, 1995; Mehrotra, 2000; Mehrotra *et al*., 2003). Also numerous cuticle fragments have been described from the coalfield (Tewari & Mehrotra, 2004; Tewari *et al*., 2005).

The terminology used in describing the leaf is after Hickey (1973) and Dilcher (1974). The identifications were made by comparing the fossil leaf, stem and fruit with that of modern taxa at the Herbarium of the Forest Research Institute, Dehra Dun, Central National Herbarium, Howrah, India, the University of Florida Modern Reference Leaf Collection (acronym: UF) at the Florida Museum of Natural History and the University of Florida Herbarium (acronym: FLAS), Gainesville, USA. and Fairchild Tropical Gardens (acronym: FTG), Miami, USA. The specimens are deposited in the Museum of the Birbal Sahni Institute of Palaeobotany, Lucknow, India.

SYSTEMATICS

Family—EQUISETACEAE

Genus—EQUISETUM L.

Equisetum sp.

(Pl. 1.1)

Description—Stem strap shaped, about 4.5 cm long by 1.5 cm wide, marked by parallel, well developed closely spaced ridges and furrows (Pl. 1.1), about 18 in number, varying from less than 1 to 1 mm apart; stem margin entire; one nodal sheath present with fused leaves and free leaf tips, the tips with possible linear extensions.

Holotype—Specimen No. BSIP 39296.

Horizon and Locality—Tikak Parbat Formation; Tirap colliery of the Makum Coalfield, Tinsukia District, Assam.

Age—Oligocene.

Number of specimens studied—One.

Discussion—The striations and a nodal sheath of fused leaves with free leaf tips are characteristic of *Equisetum*. The number of ridges for the fossil is 36, under the maximum number of 56 for *Equisetum* stems, while *Equisetum* branches are generally of 4-5 ridges (Hauke, 1963, 1978). Since *Equisetum* stems are jointed, they tend to pull apart at the nodes, leaving the joint with a sheath surrounding a hollow space. This is what we see in this fossil where the upper portion of the leaf tips have collapsed inward (Pl. 1.1). The sheath is dark in the fossil, which can be found in extant species of *Equisetum* (Hauke, 1963, 1978). The presence of

Equisetum is new in the Oligocene of India, although unidentified longitudinally striated stems or branches have been noted in this flora (Seward, 1912).

Equisetum L. consists of 15 species found worldwide, except for Australia, New Zealand, and Antarctica and can be found alongside riverbanks, marshes and other wet areas (Hauke, 1990). Species found living in India today include *E. arvense* L., *E. diffusum* D. Don, *E. hyemale* ssp. *hyemale*, and *E. ramosissimum* ssp. r*amosissimum* (Hauke, 1963, 1967, 1978). Stems of *Equisetum* are jointed with a nodal sheath and a series of ridges and furrows that transverse the internodes and continue into the nodal sheaths. The nodal sheath is a whorl of fused, small leaves, usually with free leaf tips (Hauke, 1963, 1978, 1990).

Fossils of *Equisetum* have been found in a number of forms such as rhizomes, tubers, stems, cones, and spores. They occur from the Permian through the Mesozoic (as *Equisetites*), in the Cenozoic (as *Equisetum*) and from many parts of the world (Lamotte, 1952; Gould, 1968; Andrews, 1970; Lakhanpal *et al*., 1976; Stewart & Rothwell, 1993; Des Marais *et al*., 2003). In India, the fossils are generally described as *Equisetites rajmahalensis* (Oldham & Morris) Feistmantel from the Upper Jurassic of Rajmahal Hills, Bihar (Oldham & Morris, 1863); Lower Cretaceous of Kutch, Gujarat (Roy, 1965; Lakhanpal *et al*., 1976) and Middle Cretaceous of Gujarat (Borkar & Chiplonkar, 1973). *Equisetum* sp. is also recorded from the Jurassic to Early Cretaceous of Narsinghpur District, Madhya Pradesh (Zeba-Bano, 1980). Its spores, *Equisetosporites* are known from the Eocene of the Cambay Basin (Saxena, 1991).

Family—CLUSIACEAE

Genus—MESUA L.

Mesua antiqua Awasthi, Mehrotra & Lakhanpal, 1992

(Pl. 1.2-1.3)

Description—Fruit ovate, length 4-4.2 cm, width 2.1-2.5 cm, thickness 6 mm. Base rounded with an attachment scar, apex constricted to a beak (Pl. 1.2). Surface striated, striations very closely spaced, about 8 per mm and coalescing basally and apically, ~60-75 striations (Pl. 1.3).

Figured specimens—Specimen Nos. BSIP 39294-39295.

Horizon and Locality—Tikak Parbat Formation; Bargolai Colliery of the Makum Coalfield, Tinsukia District, Assam, India.

Age—Oligocene.

Number of specimens studied—Two.

Discussion—The general shape, size and surface striations of this fossil suggest an affinity with extant species of *Mesua* L. fruits, although the fossil is slightly larger in length. Fruits of *Mesua ferrea* L. (FTG 53116) are globose, 2.2-3.1 x 1.7-2 mm, apex beaked, 8-10 ridges per mm and thinly woody which may explain the thin exterior layer on specimen BSIP 39295 (Pl. 1.2).

Mesua L. consists of five species of trees found from Sri Lanka and India to Sumatra (Stevens, 2007). The fruits are ovoid to globose, with a conical point, striated and thinly woody (Kostermans, 1980).

Fossils of *Mesua* have been found in India as leaves, wood and fruits. Leaves of *Mesua tertiara* Lakhanpal are reported from the middle Eocene of Rajasthan (Lakhanpal, 1964; Kundu, 2006) and the lower Siwalik sediments of Koilabas, Nepal (Prasad, 1989) while wood of *Mesuoxylon arcotense* Lakhanpal and Awasthi is reported from the Miocene/Pliocene of Tamil Nadu (Lakhanpal & Awasthi, 1964; Kundu, 2006). Fossil leaves and fruits of *Mesua* have been previously described in the Makum Coalfield as *Mesua antiqua* Awasthi *et al*. (Awasthi *et al*., 1992; Awasthi & Mehrotra, 1995).We were able to add new information such as an attachment scar and striation morphology to the characters already known for this fossil.

Family—LAURACEAE

Genus—DAPHNOGENE UNGER

Daphnogene makumensis sp. nov.

(Pl. 1.4-1.5)

Specific diagnosis—Leaf simple, lamina elliptic, margin entire, base acute. Venation basal acrodromous, perfect, extending 80% leaf length, equidistant to the margin. Tertiary veins arising exmedially from lateral veins at acute angles, extending to the margin, unbranched, closely placed and fine.

Description—Leaf incomplete and simple, microphyll; preserved length of lamina 4 cm (estimated total length 5-6 cm); maximum width 1.8 cm at middle 1/3 leaf length from base, lamina elliptic; apex missing; base slightly asymmetrical, convex, acute (about 60°); margin entire; texture appears chartaceous; petiole missing; venation basal acrodromous, perfect (one mid vein and two basal, strongly developed lateral veins) (Pl. 1.4-1.5); mid vein moderately thick; basal lateral secondary veins arising at acute angles, moderately thick, running apically in convergent arches and extending 80% of leaf length, equidistant to the margin; intersecondary and intramarginal veins not present; tertiary veins preserved at one place, arising exmedially from the lateral veins at acute angles (45°), unbranched, more or less straight, extending to the margin, rarely uniformly curved, oblique in relation to mid vein, about 2-3 mm apart, closely placed, fine; trichome base impressions and clusters of 2-3 trichome impressions observed on the surface; further details not observed.

Holotype—Specimen No. BSIP 39292.

Paratype—Specimen No. BSIP 39293.

Horizon and Locality—Tikak Parbat Formation; Tirap Colliery of the Makum Coalfield, Tinsukia District, Assam.

Age—Oligocene.

Number of specimens studied—One (part and counterpart).

Discussion—One important character of this fossil leaf is the acrodromous venation, which can be found in at least 21 families (Lakhanpal & Guleria, 1981). Characters found in this fossil leaf, such as an unlobed elliptic leaf with entire margins and three main basal acrodromous veins, are found in Coriariaceae, Euphorbiaceae, Lauraceae, Menispermaceae, Myrtaceae, Rhamnaceae, Smilacaceae and Ulmaceae. In *Rhodamnia spongiosa* B. Gray (Myrtaceae), there are exmedial secondary veins branching off the basal acrodromous veins which are not evident in the fossil leaf (Christophel & Hyland, 1993). In *Zizyphus inermis* Merrill (Rhamnaceae, UF2413) the perpendicular percurrent tertiary veins are very strong, while in the fossil leaf tertiary venation is weak and not obvious for the most part. In Ulmaceae, most leaves are ovate with a distinct asymmetrical base, except in *Celtis philippensis* K.F. Kenneally where the leaves are elliptic and the base is slightly asymmetrical (Christophel & Hyland, 1993). In *Abuta grandifolia* (Mart.) Sandw. (Menispermaceae, UF5130), the leaf is coriaceous and with a swollen petiole, while the fossil leaf is chartaceous although the petiole is missing. In *Elaeophora abutaefolia* Ducke (Euphorbiaceae, UF1110) and *Coriaria* sp. (Coriariaceae, UF5690) there are pinnate venation above the middle portion of the leaf, although in *Coriaria* there are also strong venation near the leaf base that join the superadjacent pinnate veins. Such venation is not evident in the fossil leaf. In *Smilax laurifolia* L. (Smilacaceae, UF5293) the acrodromous veins are closer to the margin and end in an acute apex and tertiary vein angle is acute with respect to the midvein. In the fossil leaf, the acrodromous veins are equidistant between the midvein and margin, although the tertiary venation with respect to the midvein is not preserved and the leaf tip is missing. The genera *Cinnamomum* Schaeffer, *Cryptocarya* R. Brown, *Lindera* Thunb. and *Neocinnamomum* H.

PLATE 1

All bar scales are of 5 mm.

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1. Stem of *Equisetum* sp. (Specimen No. BSIP 39296).
2-3. Fruits of *Mesua antiqua* (Specimen Nos. BSIP 39295 and BSIP 39294 respectively).
4-5. Leaf of *Daphnogene* (Type Nos BSIP 39292 (part). and BSIP 39293 (counterpart) respectively).

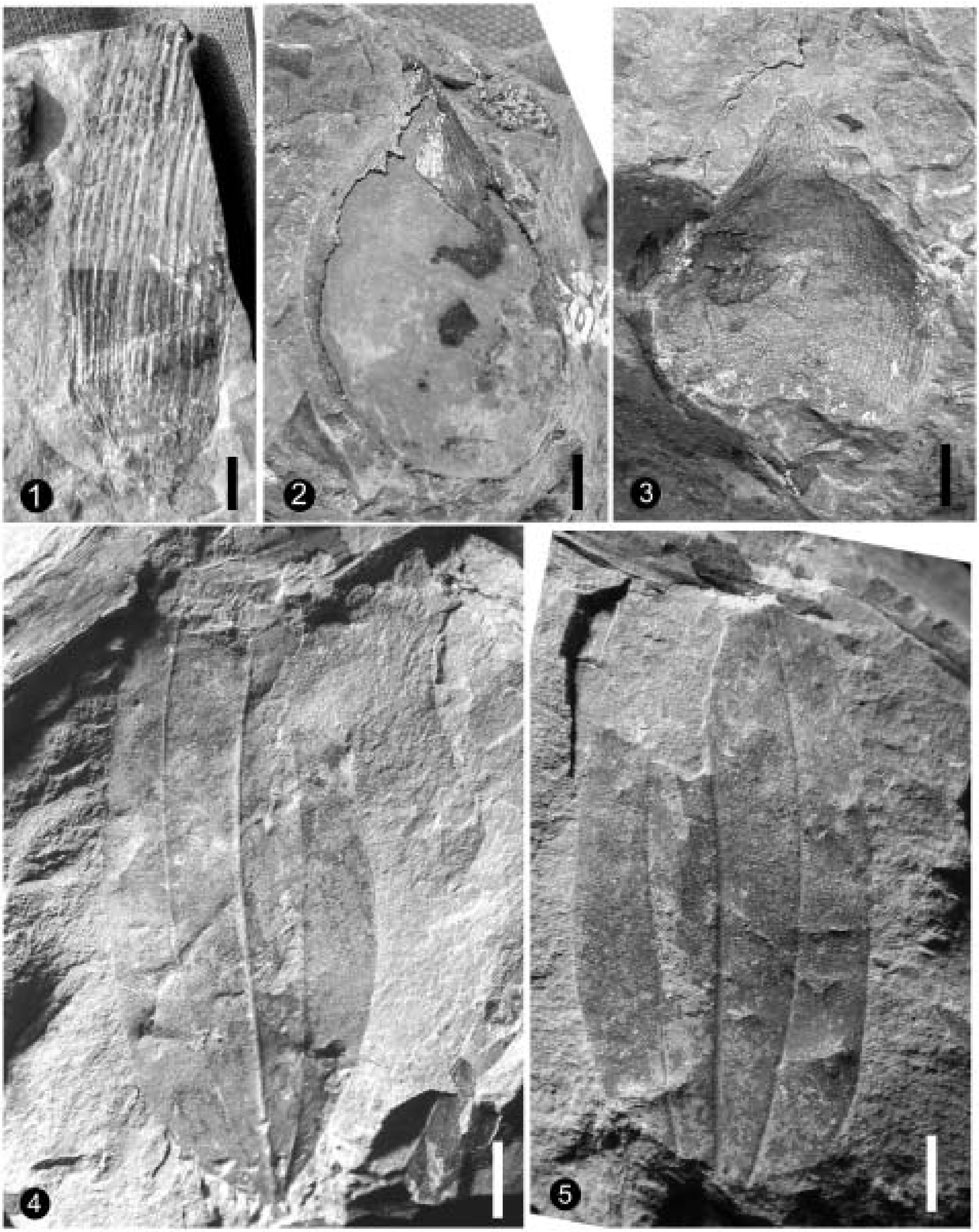

PLATE 1

Liou (Lauraceae) have morphological characters similar to the fossil leaf (Klucking, 1987; Christophel & Rowett, 1996). The lack of a leaf tip and poor preservation of tertiary venation in respect to the midvein makes determination of the fossil leaf to an extant genus difficult. All four genera are similar in shape, margin, base, apex, have basal acrodromous venation with pinnate veins above the leaf middle and strong tertiary venation in respect to the midvein and exmedial to the acrodromous veins. In *Cinnamomum* these tertiary veins are very weakly developed in the numerous species of this genus. The *Cinnamomum* species *C. camphora* Nees & Eberm., *C. cassia* Bl., *C. heyneanum* Nees, *C. japonicum* Siebold (= *C. pedunculatum* J. Presl), *C. keralaense* Kosterm., *C. macrocarpum* Hook.f., *C. malabathrum* (Burm. f.) Bl., *C. parthenoxylon* (Jack) Meisn., *C. perrottetii* Meisn., *C. riparium* Gamble, *C. sulphuratum* Nees, *C. tamala* (Buch.-Ha.) T. Nees & C.H. Eberm., *C. verum* J. Presl, *C. walaiwarense* Kosterm. and *C. zeylanicum* Bl. were carefully studied and numerous variations in venation were found to be present in many of these species. Even with the same species, such as *C. camphora*, venation can be pinnate or acrodromous. Fossil leaves with acrodromous venation and an entire leaf margin that are *Cinnamomum*-like have been placed in the form genus *Daphnogene* (Kvacek, 1971, 2004). We have followed this convention in this paper.

Daphnogene Unger (1850) is a form genus used for cinnamomoid type of leaves with three basal veins which lack cuticle and fine venation necessary for generic determinations (Kvacek, 1971). The leaf described here is considered similar to *Cinnamomum* Schaeffer (1760), a genus that consists of about 350 species, mostly evergreen trees and shrubs, found mostly in tropical and subtropical Asia (Rohwer, 1993), with 16 species living in India today (Santapau & Henry, 1973). This genus is also found in Central and South America and a few species in Australia and the Pacific Islands (Rohwer, 1993). Today, it appears to have had a broader distribution in the past as evidenced by the fossil record of its pollen (Muller, 1981), leaves (Lakhanpal & Guleria, 1981), wood (Awasthi & Ahuja, 1982) and fruits (Pringen *et al*., 1994).

Muller (1981) noted that *Cinnamomum* pollen is rarely found because of its low production and ephemeral exine. *Inaperturopollenites palaeogenicus* and *I. spicatus*, from the Upper Palaeocene of France and Belgium respectively, are the only two reliable pollen records of *Cinnamomum*. Fossil leaves of *Cinnamomum* have been described under four generic names, *Cinnamomum* Schaeffer, *Cinnamomiphyllum* Nathorst (1888), *Cinnamomophyllum* Kräusel & Weyland (1950) and *Cinnamomoides* Seward (1925). A detailed listing by Lakhanpal and Guleria (1981) noted 86 species of *Cinnamomum*, one species of *Cinnamomiphyllum*, nine species of *Cinnamomophyllum* and five species of *Cinnamomoides*, from New Zealand to Greenland and from Japan to Brazil. A comprehensive review of all these reports is recommended but beyond the scope of this paper. Additional species of *Cinnamomum* have been recorded from China, India and Nepal (Li, 1989; Prasad, 1989; Antal & Awasthi, 1993; Tao, 2000). *Cinnamomum*-like leaves with associated fruits and *Litsea*-like leaves with characteristic cuticle have been described under the genus *Daphnogene* Unger (Kvacek, 2004). Fossil wood of Lauraceae are homogeneous in structure and are usually described under the organ genus *Laurinoxylon* Felix (1883), although two of its species are similar to wood of *Cinnamomum* (Awasthi & Ahuja, 1982). Fossil fruits of *Cinnamomum* are known from the London Clay flora (Reid & Chandler, 1933; Chandler, 1961) and the Middle Miocene of Western Germany with the revision of *Homalanthus costatus* Mai to *Cinnamomum costatum* (Mai) Pringen *et al*. (Pringen *et al*., 1994). The earliest record of *Cinnamomum*, *C. paluxyense* Ball (1937) is described from the Lower Cretaceous of Paluxy sands, Texas, USA.

Fossils of *Cinnamomum* in India are known from leaves and wood. Leaves of *C. eokachchhensis* Lakhanpal & Guleria and *C. miokachchhensis* Lakhanpal & Guleria are from the Eocene (Berwali Formation) and Miocene (Khari Formation) respectively (Lakhanpal & Guleria, 1981, 1982; Srivastava, 1991). Leaves of *C. palaeotamala*

Lakhanpal & Awasthi and *Cinnamomum* sp. are from the Miocene/Pliocene (Siwalik Series) of Bhikhnathoree and Darjeeling respectively (Lakhanpal & Awasthi, 1984; Srivastava, 1991; Antal & Awasthi, 1993) and *Cinnamomum* sp. are from the middle Miocene (Warkalli Formation) of the Kerala Coast (Awasthi & Srivastava, 1992).

Fossil wood resembling *Cinnamomum* have been described as *Laurinoxylon deccanenis* Bande & Prakash, *L. deomaliensis* Lakhanpal *et al.* and *L. namsangensis* Lakhanpal *et al.* from the Miocene-Pliocene of Arunachal Pradesh (Bande & Prakash, 1980; Lakhanpal *et al*., 1981), *L. tertiarum* Prakash & Tripathi from the Miocene of Assam (Prakash & Tripathi, 1974) and *L. varkalaensis* Awasthi & Ahuja from the Miocene-Pliocene of Kerala (Awasthi & Ahuja, 1982).

The fossil leaf was compared with previously described fossil species of *Cinnamomum* from the Indian Subcontinent. *Cinnamomum eokachchhensis* Lakhanpal & Guleria and *C. miokachchhensis* Lakhanpal and Guleria (Lakhanpal & Guleria, 1981, 1982), although they resemble the fossil leaf, they differ in having intramarginal veins which is not present in the fossil leaf. In *C. palaeotamala* Lakhanpal and Awasthi and *Cinnamomum* sp. the acrodromous veins are suprabasal (Lakhanpal & Awasthi, 1984; Awasthi & Srivastava, 1992). In *Cinnamomum* sp. there is a size difference and the areoles are well-developed (Antal & Awasthi, 1993). In *C. mioinctum* Prasad the shape is obovate and the venation is pinnate (Prasad, 1989). Although the preservation of the fossil leaf is not ideal, there are a number of character differences from other described fossil *Cinnamomum*-like leaves so we propose the new species *Daphnogene makumensis*.

Prakash and Tripathi (1974) reported wood resembling *Cinnamomum* from the middle Miocene sediments of Assam, yet due to the homogeneous nature of lauraceous woods, it can not be said with certainty that it belongs to *Cinnamomum*.

DISCUSSION

The Oligocene flora from the Makum Coalfield of India provides a rich history of taxonomic descriptions of fossil plants, from generalized "dicotyledonous plants" and *Phyllites* sp. (Seward, 1912), to present day extant genera designations. Caution is required when working with fragmented leaves and that is evident in the *Cinnamomum*–like leaf of *Daphnogene* presented here.

In this report, we describe two new species, *Equisetum* and *Daphnogene*, which brings the total number of genera, of the Makum Coalfield flora, to 28, plus one new family of Equisetaceae. The presence of *Equisetum* in the Oligocene of India is of interest because it is at this time that the diversification of *Equisetum* is presumed to have occurred, forming the two subgeneric groups *Hippochaete* and *Equisetum* (minus *E. bogotense*) (Des Marais *et al*., 2003). The potential for new information, from well-preserved new specimens of previously described taxa, is always possible. This new information may or may not confirm the systematic placement of that taxa. Here, we confirm the placement of *Mesua antiqua* with new and expanded characters. Placing the tri-nerved fossil leaf into the form genus *Daphnogene* represents appropriate caution in trying to identify a partial leaf to extant genera with limited morphological data. Although this leaf could be placed in four different Lauraceous genera, placing it near *Cinnamomum* is based only on the strength of the tertiary veins.

Daphnogene and the other known taxa from the Oligocene Makum Coalfield (Awasthi *et al.*, 1992; Awasthi & Mehrotra, 1995; Mehrotra, 2000; Mehrotra *et al*., 2003), suggests the existence of tropical evergreen to moist deciduous forests with riparian elements (Champion & Seth, 1968). The presence of *Equisetum* suggests a deposition in a low wet area while the occurrence of *Avicennia*, *Barringtonia*, *Entada*, *Nypa*, *Rhizophora* and *Terminalia catappa* suggests a deltaic or lagoonal deposition (Awasthi & Mehrotra, 1995; Misra, 1992a, b).

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